

Sensitivity to Longitudinal VBS at 100 TeV

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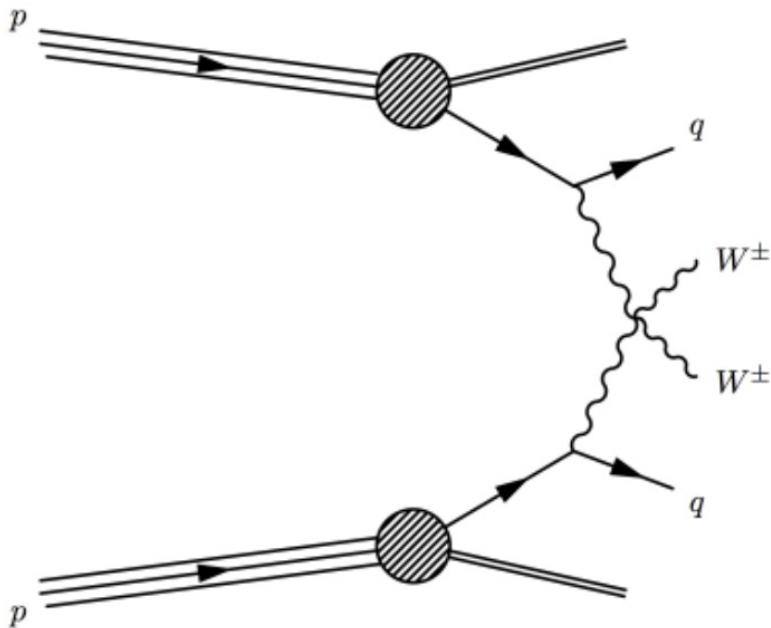
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Introduction

- **Aim:** Study the sensitivity to longitudinal Vector Boson Scattering (VBS) at a 100 TeV hadron collider
 - An important medium to test electroweak symmetry breaking (Higgs contribution cancels divergences)
 - Also sensitive to benchmark models such as a doubly charged Higgs
- We will explore the fully leptonic $W^\pm W^\pm jj$ channel
 - offers the largest electroweak to strong production cross-section ratio among VBS processes



Signature

- 2 same-sign leptons, large MET, 2 forward jets

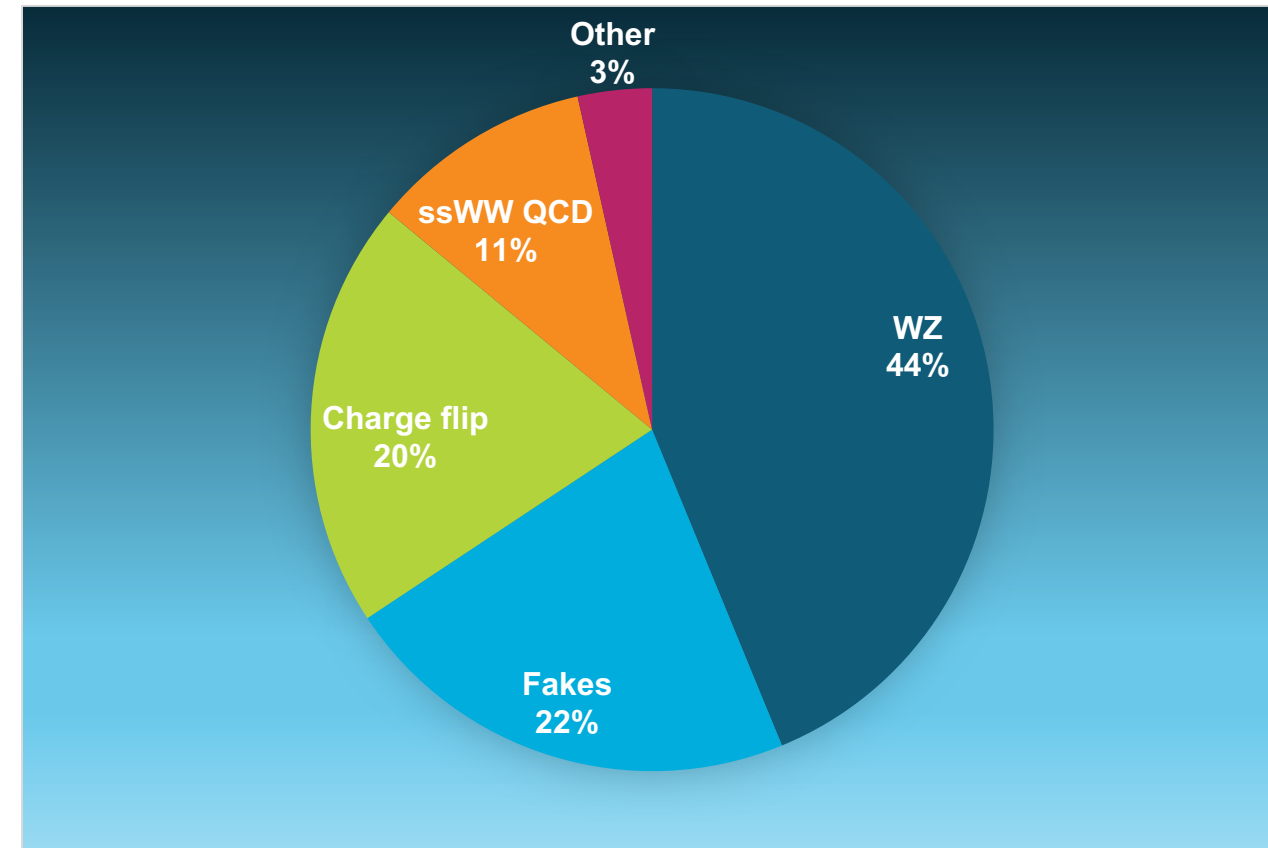
We will measure all polarization fractions:

- Both W 's longitudinally polarized (LL channel)
- One W is longitudinally polarized, the other is transversely polarized (LT+TL channel)
- Both W 's are transversely polarized (TT channel)

Backgrounds

- Only **same sign WW QCD**, **WZ (QCD and EW)** and **tZq** backgrounds are considered for now
- All detector-specific backgrounds (charge-flip, fakes) will be ignored
- However, we could also scale up the Monte Carlo to reflect something similar to the composition in the 13TeV ATLAS analysis
- WZ was the dominant background in ATLAS' 13 TeV same sign *WW* [analysis](#)
- All other smaller backgrounds will be ignored entirely

❖ Background composition in 13 TeV same sign WW analysis in ATLAS



Status and plans

- Our primary goal is the sensitivity measurement to longitudinal VBS but we'll measure all polarization fractions
 - Additional studies such as sensitivity to doubly charged Higgs might be followed up in a separate paper
- Production of signal sample is in progress
 - So far, we have generated all signal samples and performed some basic generator level validation (more on next slides)
 - We use MG5 3.1.1+ PYTHIA8 and run through Delphes (a generic FCC detector)
- For background processes, we have generated ssWW QCD, WZ EW and QCD samples. tZq is in progress
 - Validation of these samples is also in progress
 - We have also contributed to the validation of central samples (more on next slides)
- For analysis, we are developing part of the analysis framework
 - Some of the analysis chain will use an already existing BNL framework (also used for the [yellow report](#))
 - Currently just working with rivet for our validation studies

Signal sample details

- Generator used: MADGRAPH5 3.1.1+PYTHIA8 with dipole recoil ON
- PDF set: NNPDF2.3 NLO
- Number of events generated: 200K per sample
- C.M energy: 100 TeV

Generator cuts

- Lepton $p_T > 10$ GeV
- Jet $p_T > 10$ GeV
- $m_{jj} > 300$ GeV

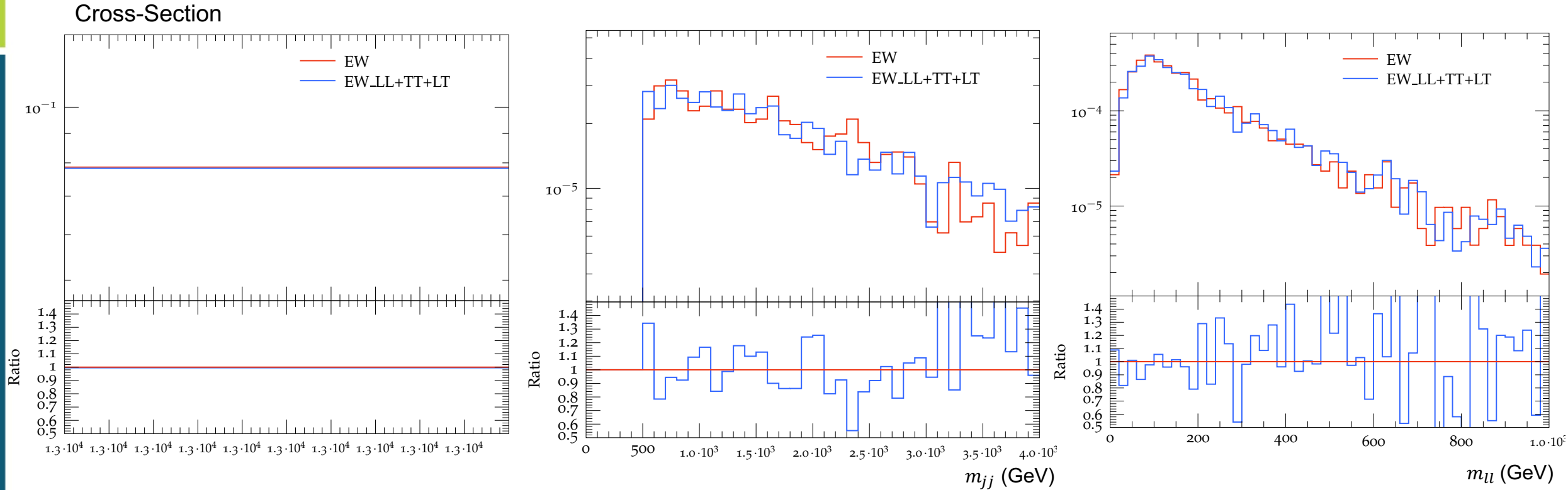
Sample	Cross-section
Inclusive	0.778 pb
LL	0.064 pb
LT+TL	0.245 pb
TT	0.470 pb
LL+LT+TL+TT	0.779 pb

Cuts applied for validation in same-sign WW rivet routine

- 2 same-sign leptons, $p_T^l > 20$ GeV
- nJets ≥ 2 , $p_T^j > 30$ GeV, $|\eta_j| < 4.5$
- $m_{jj} > 500$ GeV
- Min $\Delta R_{ll} > 0.3$
- MET > 40 GeV

❖ Cross sections defined in the WW center of mass frame

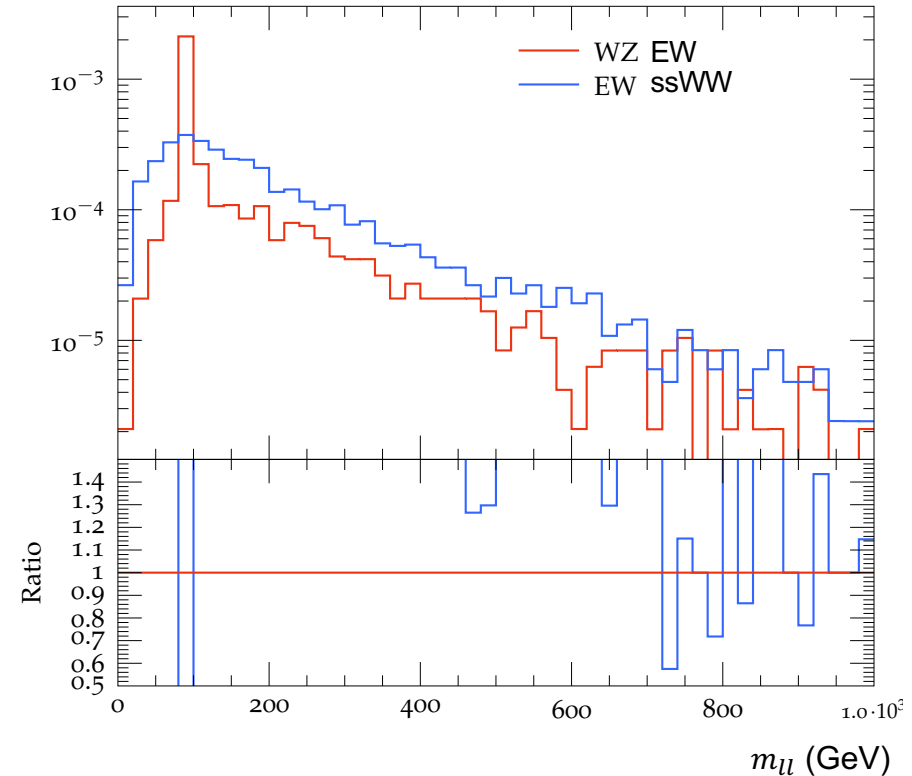
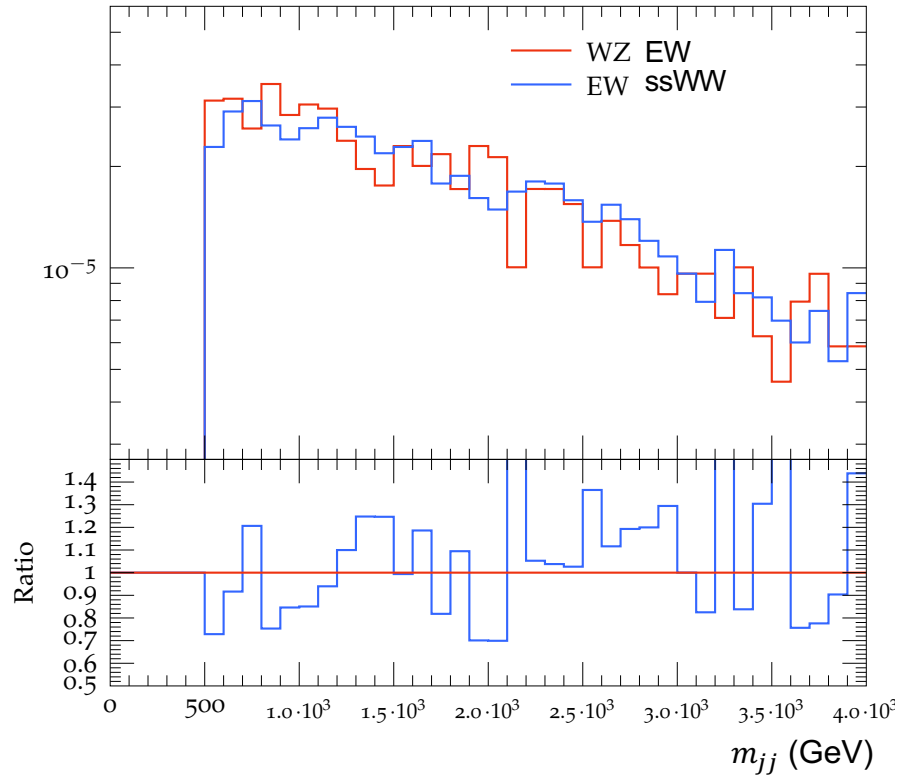
Validation of signal samples



- This validation compares the inclusive sample to the combination of the individual polarizations
- The cross-sections match and all other distributions are similar. Plots will be re-done with higher statistics

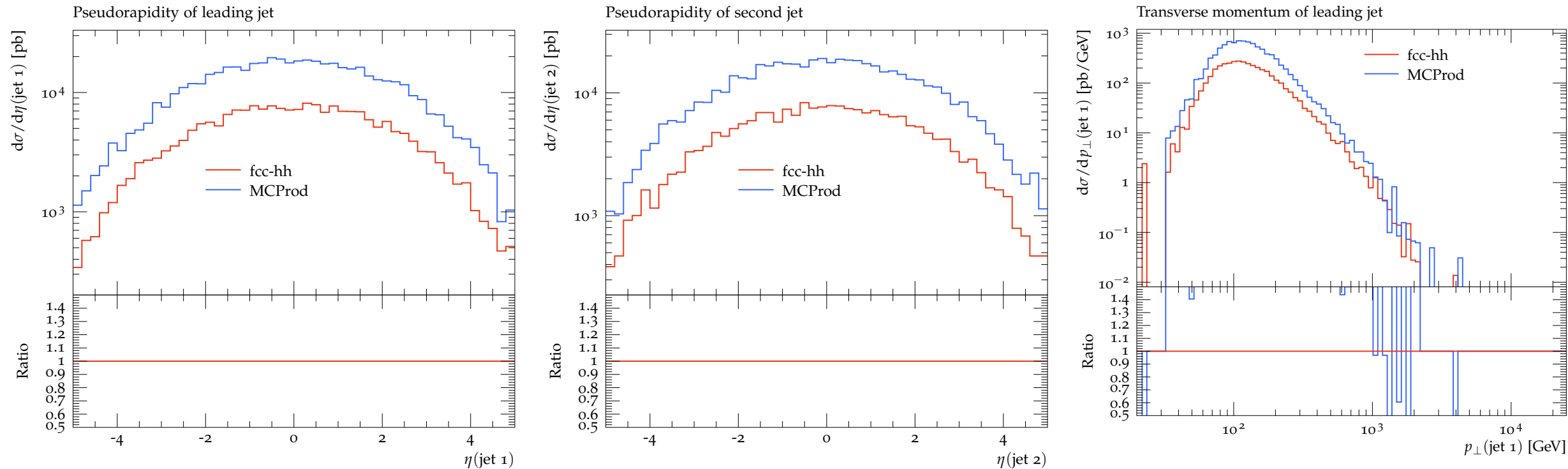
Validation of WZ EW samples

- Generated with same setup as signal samples, but with $m_{ll} > 60$ GeV
- WZ EW cross-section: 1.34 pb



- These distributions are a comparison between WZ EW and ssWW EW
- Same rivet routine is used but without the same sign cut
- As expected, the two samples are similar and there's a clear Z peak in the m_{ll} distribution

Validation of central samples



- The MC_JETS rivet routine was used for these plots and the comparison is made to FCC samples
- Disagreement between the two samples was quite obvious
- This validation also led to the realization that there was no parton matching done in Pythia
- The current samples are therefore not usable and a production of new samples is in progress
- New production also includes some other features that were planned before

Summary

- ✓ Focusing only on the sensitivity measurement to longitudinal VBS
 - ✓ However, we will measure all polarization fractions
 - ✓ Production of signal samples is done and their validation is progressing well
 - ✓ Production and validation of background samples is also progressing well
 - ✓ Development of part of the analysis framework is in progress
 - ✓ For part of the analysis chain, we will use an already existing BNL framework
 - ✓ We have contributed to the validation of central background samples
 - ✓ No parton matching was done in Pythia for central samples and a new production is underway
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- ❖ We expect to be ready with the white paper result by March 2022
 - ❖ Expect to continue studies on benchmark models such as a doubly charged Higgs

Back-up

Signal sample details

- Generator used: MADGRAPH5 3.1.1+PYTHIA8 with dipole recoil ON
- Generated processes:
 - generate pp > j j W^+W^+ QCD = 0 QED = 4, $W^+ \rightarrow l^+ \nu_l$
 - generate pp > j j $W^+\{0\} W^+\{0\}$ QCD = 0 QED = 4, $W^+ \rightarrow l^+ \nu_l$
 - generate pp > j j $W^+\{0\} W^+\{T\}$ QCD = 0 QED = 4, $W^+ \rightarrow l^+ \nu_l$
 - add process pp > j j $W^+\{0\} W^+\{T\}$ QCD = 0 QED = 4, $W^+ \rightarrow l^+ \nu_l, W^+ \rightarrow ta^+ \nu_l$
 - add process pp > j j $W^+\{0\} W^+\{T\}$ QCD = 0 QED = 4, $W^+ \rightarrow ta^+ \nu_l, W^+ \rightarrow l^+ \nu_l$
 - add process pp > j j $W^+\{0\} W^+\{T\}$ QCD = 0 QED = 4, $W^+ \rightarrow ta^+ \nu_l$
 - generate pp > j j $W^+\{T\} W^+\{T\}$ QCD = 0 QED = 4, $W^+ \rightarrow l^+ \nu_l$
- For each sample, we add a process for the W^-W^- case
- Note: decay to taus has to be added separately for the mixed polarizations. see [launchpad](#)
 - taus are also not included in the particle definition. E.g we use “define l+ = e+ mu+”
- PDF set: NNPDF2.3 NLO
- Number of events generated: 200K per sample
- C.M energy: 100 TeV

Central background samples

Dataset name	Physics process
Bj-4p	γ or on-shell W , Z
Bjj-vbf-4p	γ or off-shell W , Z , H in VBF topology
BB-4p	Diboson (γ , W , Z) processes
BBB-4p	Tri-boson (γ , W , Z) processes including BH
LL-4p	Non-resonant dileptons (including neutrinos)
LLB-4p	Non-resonant dileptons with an on-shell boson
H-4p	Higgs
tj-4p	Single top (s- and t-channel)
tB-4p	Single top associated with a boson
tt-4p	$t\bar{t}$ pair production
ttB-4p	$t\bar{t}$ associated with γ , W , Z , H

Central samples: Validation Procedure

- ❖ Validation involved comparing snowmass (MCProd) samples to fcc-hh samples at truth level
 - Example: **ttbar sample**
 - Number of events: 10,000
 - fcc-hh: /eos/experiment/fcc/hh/generation/lhe/mg_pp_tt012j_5f/events_022118229.lhe.gz
 - eos is not mounted on the snowmass cluster
 - Sample was thus copied to BNL cluster and converted to hepmc
 - Run through some generic and same-sign WW rivet routines
 - MCProd: /collab/project/snowmass21/data/smmc/v0.1/r1/100TeV_tt.tar.gz/mgstep/out_5423_13.lhe.gz
 - Converted to hepmc on the snowmass machine and copied to BNL cluster
 - Run through some generic and same-sign WW rivet routines

Differences between fcc-hh and Mcprod samples

Fcc-hh sample	MC prod sample
MG v2.5.4	MG v3.1.1
Lhaid: 260000 (NNPDF3.0 NLO)	Lhaid: 230000 (NNPDF2.3 NLO)
Jet pT > 5 GeV	Jet pT > 20 GeV
Lepton pT > 5 GeV	-
Jet eta < 8	Jet eta < 5
Lepton eta < 8	-
Mll > 20 GeV	-
Xqcut: 60	Xqcut: 30
Cross-section: 0.40×10^5 pb	Cross-section: 1.03×10^5 pb